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NOVA GEMINORUM NO. 2 AS A WOLF-RAYET STAR

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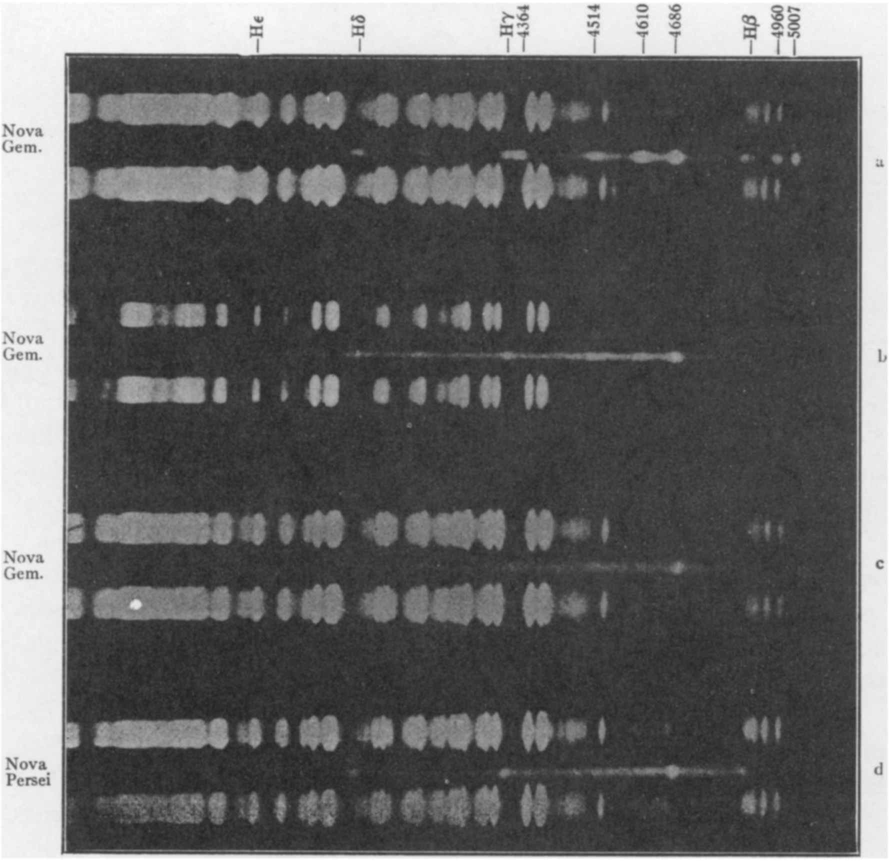
It has been known for many years that the spectrum of temporary stars or Novae develops in a later stage into a spectrum nearly identical with that of planetary nebulae. First observed in the case of Nova Aurigae of 1891, the same result has been found to hold for all of the temporary stars observed since that time, including the most important Nova of recent years, Nova Persei of 1901. The question whether this nebular spectrum may be regarded as the final stage in the development of the spectra of temporary stars is of great importance because of its immediate bearing on the order of evolution of stars. In his book on Stellar Movements Eddington says in this connection:[1] "There is some justice in a remark of R. T. A. Innes: 'The fact that we have seen a star change into a nebula ought to outweigh every contrary speculation that stars originate from nebulae.' "

The faintness of the Novae in the later stages of their history has made observations of their spectra exceptionally difficult. In 1906, however, Hartmann[2] obtained an observation of Nova Persei, then of about the eleventh magnitude, which showed that two of the principal nebular lines had disappeared, and he called attention to the strong similarity of its spectrum to that of one of the Wolf-Rayet stars. Since that time the work has been taken up at Mount Wilson, with the 60-inch reflector and extended to include observations of other Novae.

Photographs of the spectrum of Nova Geminorum No. 2 (1912) taken during the past year have shown some peculiarly interesting developments in this most recent of the temporary stars. In February 1914, the spectrum consisted of prominent bright bands joined by a continuous spectrum of rather feeble intensity. These bands are those so conspicuous in the spectra of nebulae, the more important in order of brightness being λ 4686, 5007, 4610, 4364, 4960 and the hydrogen lines, *Hβ*, *Hγ*, *Hδ* and *Hε*.

During the summer the star could not be observed on account of its position, but in November another photograph was secured. This showed some extraordinary changes. In addition to a great increase in the intensity of the continuous spectrum, the plate showed the disappearance of the chief nebular line at λ 5007 and the line so commonly associated with it at λ 4364, and a marked reduction in the intensity of λ 4610. The absence of λ 5007 is especially remarkable in view of the presence, although in reduced intensity, of the nebular line at λ 4960. These two lines, known as N_1 and N_2 of the nebular spectrum, without exception so far as we know, have always been observed together, and vary in intensity together, λ 5007 being about twice as strong as λ 4960.



Although no common origin has been established for these lines this peculiarity in behavior might be compared to the disappearance of D_2 in the sodium spectrum, while D_1 persisted in reduced intensity.

Another photograph of the spectrum of the star was obtained in April 1915. This showed that all of the characteristic nebular lines had disappeared, the line λ 4686 which is common to the spectra both of nebulae and Wolf-Rayet stars, and the hydrogen lines alone remaining. There are, however, traces of some of the Wolf-Rayet bands and the continuous spectrum is very strong.

In a communication published by us in 1914[3] we compared the spectrum as then observed of Nova Geminorum No. 2 with that of three of the temporary stars discovered in previous years. Two of these, Nova Aurigae (1891) and Nova Persei (1901), were found to have strong continuous spectra on which the hydrogen lines appeared as bright bands of moderate intensity. No characteristic nebular lines were present in their spectra, but λ 4686 was very prominent in Nova Persei, and present, though much less bright, in Nova Aurigae. The close agreement of these spectra and especially that of Nova Persei with the spectrum of some of the Wolf-Rayet stars was referred to in the course of the comparison. The interesting result now appears that the spectrum of Nova Geminorum No. 2 has also developed into that of a Wolf-Rayet star, being essentially identical with that of Nova Persei, although the hydrogen lines are somewhat weaker. Measurements of the negatives of Nova Persei and Nova Geminorum show the presence of the following Wolf-Rayet bands in addition to λ 4686 and the hydrogen lines:

Nova Persei......................	4021	4200	448	4514	454	461	4634
Nova Geminorum................	402	4199	444	4512		461	469

In Plate I are shown direct enlargements of three spectra of Nova Geminorum No. 2 and one spectrum of Nova Persei. The enlargement is about 17 fold. The dates of the photographs are as follows:

	Date	*Exposure time*
Nova Geminorum (a)........................	1914, Feb. 22	2 hours
Nova Geminorum (b)........................	1914, Nov. 16	2 “
Nova Geminorum (c)........................	1915, Apr. 10–12	8 “
Nova Persei (d)........................	1913, Nov. 27	8 “

The photograph of April 10–12 was taken under very poor observing conditions.

The especial feature of interest attaching to these results is the fact that a continuous series of observations in the case of Nova Geminorum No. 2 has shown the development of the spectrum of this star through the successive stages characteristic of Novae into one very strongly resembling that of planetary nebulae; and then, by the gradual elimination of the nebular lines and their replacement by Wolf-Rayet bands, into a spectrum identical with this characteristic type of stellar spectra. It appears very probable from the observations of Nova Aurigae and Nova Persei that this stage of development is to be considered as in the nature of a permanent one. It is of interest to note, however, that the period required to reach this condition may be quite variable for different stars, since the nebular lines λ 5007 and λ 4960 were still by far the most prominent feature of the spectrum of Nova Lacertae (1910) as recently as the autumn of 1913. It seems entirely possible that the nebular lines found in the case of Novae are extraneous to the stars themselves and due to material in which they are involved. Of especial importance in this connection is the recent discovery by Wright[4] that the central star in certain planetary nebulae has the Wolf-Rayet type of spectrum.

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[1] *Stellar Movements and the Structure of the Universe,* p. 156.

[2] *Astr. Nachr. Kiel,* **177**, 113 (1908).

[3] *Contrib. Mt. Wilson Solar Obs.,* No. **87**; *Astrophys. J.,* **40**, 294 (1914).

[4] *Astrophys. J.,* **40**, 466 (1914).

A SINGULAR DARK MARKING ON THE SKY

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In the search for dark or vacant regions in the sky I have photographed a number of very remarkable places, such as those near ρ *Ophiuchi* and θ *Ophiuchi*, and elsewhere.

These regions are generally connected with the presence of diffused nebulosity, but I have found several cases in which a well defined dark object seems superposed on the sky itself without any visible presence of ordinary nebulosity. One of these, and perhaps the most remarkable on account of its well defined character and singular form, is in the position: (1855.0)$\alpha = 20$ h. 48 m.; $\delta = +59°.6$, in Cepheus (see Plate). It resembles an irregular, roughly torn and curved opening through which a darker region is visible. It is one degree long and narrows down to something like 3′ across at its western end. It seems to be a part of the background of the sky independent of the starry stratum (there are no indications whatever of nebulosity immediately about it), and is appar-